Virtual assistant for first responders using natural language understanding and optical character recognition

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ABSTRACT

Commercial deep learning capabilities are available for many applications such as computer vision processing and intelligent chat bots. The Google Cloud Platform product Google Dialogflow provides lifelike conversational artificial intelligence (AI) using machine learning (ML) to generate natural conversations between computers and humans. This ML utilizes natural language understanding (NLU) to recognize a user's intent and extracts key information into a form of entities. We have developed a user-friendly application through understanding the hazardous material database, first aid safety guidelines and observing the process of first responders who access this information in the field. We created the Trusted and Explainable Artificial Intelligence for Saving Lives (TruePAL) virtual assistant using Dialogflow[1] and TensorFlow[2] paired with EasyOCR.[3] The chatbot supports first responders by providing voice interaction which helps limit additional steps such as browsing through multiple categories when searching for information. Using feedback from our field interviews, the voice interface has been developed to enable the first responder to focus on the immediate emergency. With less distractions, the first responder is able to engage the incident more effectively. The partial hands-free TruePAL chatbot assistant improves the accessibility to the correct guidance by an average of 1.9 seconds compared to the widely used application, NIH WISER, which requires full attention to operate. We combined this intelligent chatbot with a separate visual processing capability to produce hazardous signage analysis and generate the proper guidance for first responders. With the evolving functionality of AI tools, the use of virtual assistants in first responder technology will be an advancement, benefiting the safety of both first responders and civilians.

Keywords: deep learning, natural language understanding, artificial intelligence, machine learning, optical character recognition

1. INTRODUCTION

First responders such as Emergency Medical Technicians (EMTs), paramedics, firefighters, and police are repeatedly exposed to potentially life-threatening risks. Due to the pressure and uncertainty associated with the job, it is imperative that first responders remain flexible. Each team of first responders is required to be trained to handle a wide range of emergency situations. However, first responders still face unique risks outside their scope of preparation. In the event of an emergency, the top priority is the safety of the individuals at risk. Therefore, the situation can quickly become stressful, and as a result, first responders compromise their ability to follow protocols.[4] While safety measures exists to be followed during an emergency, first responders are still presented with situations that require quick split-second decisions that pose a risk to their safety.[5]

A spillage from a cargo truck resulting from a traffic accident exposes not only the driver of the vehicle but also individuals within the premises of the hazardous material.[6] The characteristics of the hazardous materials may be radioactive, toxic, and dispersing, requiring individuals to evacuate the premises. Among the teams of first responders, police officers are most often the first to arrive on a scene. In the event where a civilian's life is at risk due to exposure to hazardous chemicals, many police officers do not have enough time to perform a lookup of the material in the Emergency Response Guidebook[7] (ERG). The ERG contains the specific details regarding the material and safety measures. Similarly to police officers, firefighters are faced with emergency situations requiring limited time and quick action. Firefighters gather information through dispatch and access resources available to them in order to better understand the scope of the emergency before arriving. The tasks expected of the firefighters include prioritization of multiple factors such as: the material presenting a risk, the details of the environment being affected, and the extent of damage to be mitigated. In order to prevent further casualties, most often first responders are required to first surround the premise and gather as much indicative information of their surroundings to forward to HAZMAT professionals during a high risk situation. Under these circumstances, there is significant responsibility taken into consideration to balance between protecting the safety of at-risk individuals as well as themselves.

As part of the Trusted and Explainable Artificial Intelligence for Saving Lives (TruePAL) Project, supported by the Department of Transportation (DOT) and the National Highway Traffic Safety Administration (NHTSA), we aim to develop a virtual assistant using Artificial Intelligence to aid first responders with explainable recommendations, from handling hazardous material safety precautions and first aid to vehicle operation. With the wide advancement of technology and usage of mobile applications, first responders are also incorporating the usage of software applications to aid their work.[8] The U.S. National Institute of Health (NIH) has created an application known as the Wireless Information System for Emergency Responders (WISER), which is a system designed to assist emergency responders in hazardous material incidents. The application allows the user the same functionality as the physical guidebook. The interface of the application enables the user to input distinctive details such as the mixture of hazardous materials. The app also allows the ability to input environmental factors that affect the risks outcomes. From our field interviews with first responders, the WISER application proves to be useful in aiding the work of first responders. Despite the advantages of this application, using a wide array of resources during emergencies are still primary distractions for first responders.

In an effort to reduce stress and give relief for first responders, we introduce the following distinct features of our TruePAL mobile application: a voice interactive chatbot and hazard sign image recognition. With the chatbot, first responders are able to make inquiries about hazardous materials and receive contextualized, relevant responses. As for the hazard sign reader, first responders will be able to take a photo of the hazard sign and receive formatted information from the ERG. While further research on its' application may be required, this study aims to incorporate conversational AI and image recognition in the work of first responders and provide an additional solution to aid the work of first responders and contribute to their safety.

2. TRUSTED ARTIFICIAL INTELLIGENCE FOR FIRST RESPONDERS

In this study, we conducted field interviews with Los Angeles County police and fire departments to understand the determining factors that impact the work of first responders, particularly in an emergency response regarding hazardous materials and first aid.[9] During an emergency response, there exists operational phases as the first responder is preparing to alleviate the situation. The phases include safety protection, isolation and denying entry, as well as notifying the public. Compared to the active phase of alleviating the situation, the initial stages of an emergency protocol highlight the importance of an AI-enabled assistant.[10] As we present the TruePAL application as an aid for first responders, we understand the perception of humanness in artificially intelligent technology[11] is a large factor in adoption. In order for first responders to trust the application, the validation of user responses and the ability to understand context is required in the AI system. Based on our interviews, first responders find it difficult to completely rely on AI technology due to the perception of increased risks while using it. The perception is that uncertainties and associated risks that come along with each unique emergency response can create unpredictable circumstances where the virtual assistant may not be prepared to give a response.

To further investigate the details of first responders' reactions and concerns regarding the usage of AI, we interviewed specific groups of first responders such as law enforcement and firefighters. In these studies, we demonstrated a sample example usage of our application. Based on their feedback, a feasible application must include features that dynamically accommodate to all roles rather than a general application due to the notable distinction in roles between both groups of first responders. A police officer is most often the first to arrive at a scene from a call. Although the police officer is required to secure the premises and gather information when arriving at a scene, an initial reaction is to take action to ensure the safety of the individuals involved and surrounding the risk. As a result, many police officers increase their exposure to hazard risks and the situation becomes detrimental towards their safety. In comparison, firefighters must understand the materials involved in a hazardous material emergency response prior to arriving at the scene. If there is a civilian who is injured from contact with the hazardous material or if the hazardous material is affecting the surrounding environment, firefighters must determine the hazard description and its associated safety measures. On the way to an emergency, they must utilize available resources from physical guidebooks, manuals, and mobile applications such as WISER to gather information. For this reason, firefighters are under continuous pressure to make decisions from their research in limited time. Between each group of first responders, there are different tasks performed and therefore the method of information utilization varies. In order for a virtual assistant to become a reliable aid for first responders, it is important to understand the information needed and how it is used by each specific first responder in different emergencies. The assistant must be able to give contextualized and useful information within that field's domain of knowledge.[12]

3. TRUEPAL SYSTEM

Traffic-related fatality rates for law enforcement officers, firefighters, and EMS practitioners are estimated to be 2.5 to 4.8 times higher than the national average among all occupations.[13] It is estimated that emergency vehicle accidents in the United States costs $35 Billion annually.[14] In a Lean Six Sigma Green Belt study by the Miami-Dade Police Department, there were a total of 703 police car crashes in the Miami area during 2017. The total cost to the city incurred from replacing and repairing damaged vehicles, paying legal claims, and lost officer time due to crashes are estimated to be close to $6.5 Million.

In the analysis of the causes of emergency and police vehicle crashes, one of the key findings by the Miami-Dade Police Department is that emergency workers and police officers were often distracted by overwhelming information in the crowded police car cockpit. Some example sources of information inside these vehicles include: radar detector, siren switch box, police radio, LoJack system, police computer, cellphone, instrument / navigation displays, license plate reader, and back up camera.

One of the recommendations in the Miami-Dade Police study for the root causes of crashes is the need for an Artificial Intelligence (AI) technology to manage distractions of the officers in police vehicles. Voice activated machine interfaces have already been developed and deployed. For example, the 54ward Core Control System has demonstrated voice control of instruments in a police car cockpit. However, it can only understand simple voice commands from the police officer and provide simple control operations. It is not able to comprehend the officer's natural speech and provide intelligent recommendations.

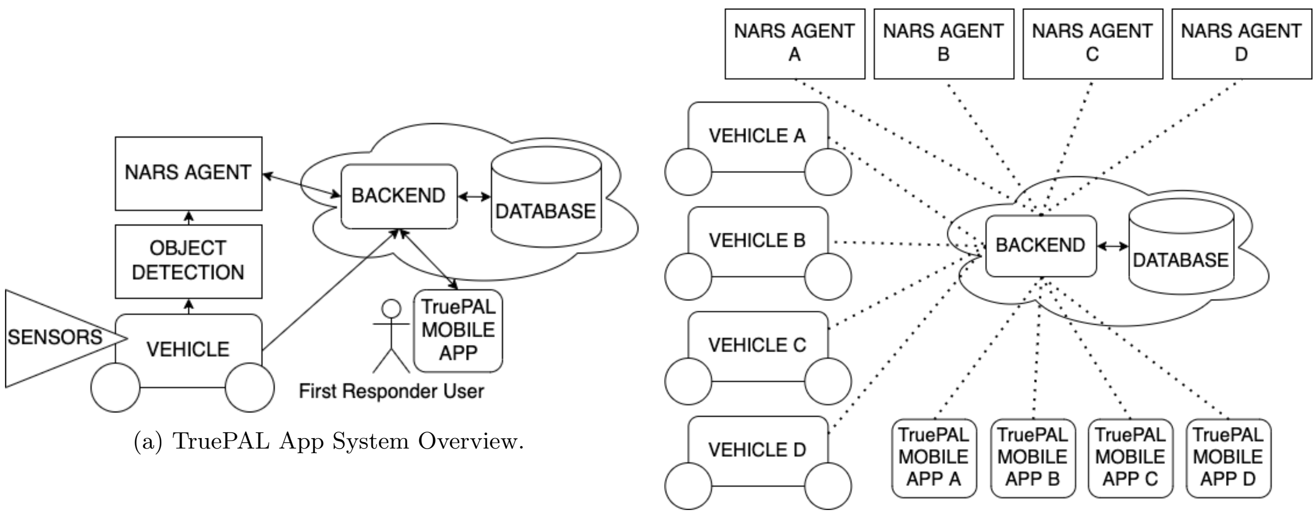
Today's deep learning AI technologies have achieved better error performance than humans in certain classification tasks such as image recognition. However, even with the current AI advancements there is no guarantee that the AI system will be able to produce the right recommendations and decisions 100% of the time. For the safety of the first responders, suspected persons, and bystanders, the AI technologies deployed in the first responder vehicles must be tested to the best of our capabilities to achieve the level of trust that humans are willing to depend on. If an accident occurs where AI technologies are involved, the recommendations and decisions made by the AI system must be explainable for the purpose of understanding the root causes and to further improve the safety of the AI system. The aim of the proposed TruePAL research is to develop a trusted AI application that is user friendly and reliable.

The objective of the TruePAL system is to develop trusted AI technology that can produce explainable recommendations and support first responder vehicle operations. The system integrates multiple sensors and instruments in the vehicle to provide needed actionable information. The goal is to provide immediate response capabilities to help first responders focus on their mission and reduce the number of accidents in real time.

We collaborated with researchers from Temple University and officers from the Miami-Dade Police Department to develop a trusted and explainable virtual AI assistant to support NHTSA in reducing traffic accidents related to first responders. The Non-Axiomatic Reasoning System[15] (NARS) is used as the primary general-purpose intelligent agent to produce explainable warnings and recommendations. The work in this research was divided up into multiple teams, the computer vision based object detection team, the Artificial General Intelligence (AGI) reasoning agent NARS team, and the application team to develop the virtual assistant. The mobile application team focused on integrating inputs from the user and outputs from the AI system. The work shown here focuses on the application development and user interface portion.

4. MOBILE APPLICATION AND SUPPORTING INFRASTRUCTURE

The TruePAL Mobile Application is a cross-platform application for both Android and iOS. The Mobile Application was built using Capacitor and the Ionic Framework with Angular. The Mobile Application is supported by a Python Flask back-end server and MongoDB database.



(a) TruePAL App System Overview.

(b) System at scale.

Figure 1: The diagram in (a) shows the application overview with one user, (b) shows the system at scale.

4.1 System Overview

The TruePAL Mobile Application and supporting back-end server are a subset of the larger TruePAL system. The focus of this paper is on the Mobile Application and back-end server. Figure 1a illustrates where the Mobile App, Back-end, and Database exist and interact with the rest of the system. The First Responder (FR) Actor has the Mobile App on their smart phone to interact with, either using touch inputs or the chat bot. The Mobile App is in communication with the back-end server. The Vehicle, simulated in the CARLA[16] virtual environment, is running an instance of the TruePAL Desktop Application which is also in communication with the back-end server. The vehicle in the CARLA virtual environment is equipped with sensors which feed data into the Object Detection and Tracking system, which then feed data into the NARS system. Finally, the NARS system is connected with the back-end.

Figure 1b highlights the system working at scale, with multiple Mobile Applications, Vehicles, and NARS Agents, all in communication with the back-end server in real time. With our cloud infrastructure use of AWS and Docker, this is built to scale up as necessary with user demand.

4.2 Core Technologies

The following sections outline each of the core services/technologies that the TruePAL app is comprised of.

Ionic Framework: We used Ionic Framework[17] as the primary User Interface toolkit to build our mobile application. The Ionic Framework is a web framework in which we can use traditional web technologies such as HTML, CSS, and JavaScript along with pre-made components to build out an application. Ionic Framework further supports integration with other libraries and frameworks to leverage their structure and features. In this application, the Ionic application is integrated with Angular.

Angular: Angular[18] is a popular web development framework / platform made by Google for building web applications in a structured manner with scalability in mind. Angular also provides a lot of tooling out of the box such as routing, state management, and testing. As such, structurally, the mobile application is an Angular project.

Capacitor: Capacitor[19] is a cross-platform run time for web applications made by Ionic. It allows the development of cross-platform mobile applications for both Android and iOS using web technologies. Capacitor is used here for two main purposes: to build and compile the Ionic / Angular web application into a mobile application for both Android and iOS, and to leverage native device features on both the Android and iOS platforms. Capacitor is used here to access the camera, microphone, and geolocation of the physical device.

MapBox: MapBox GL JS[20] is a JavaScript library for web apps that require powerful interactive maps. MapBox is used to serve the interactive map that displays both first responder on the ground and their vehicles in transit in real time. The TruePAL app also supports Google Maps[21] integration.

Google Dialogflow: Dialogflow,[1] covered in section 5.2 is a product available from Google which allows for the creation of complex virtual agents (chat bots) for domain specific applications.

TensorFlow: TensorFlow,[2] with our usage covered in section 6 is the go-to state of the art library for building machine learning models. TensorFlow is used to create a machine learning model for identifying and extracting hazardous material signs from images in real time.

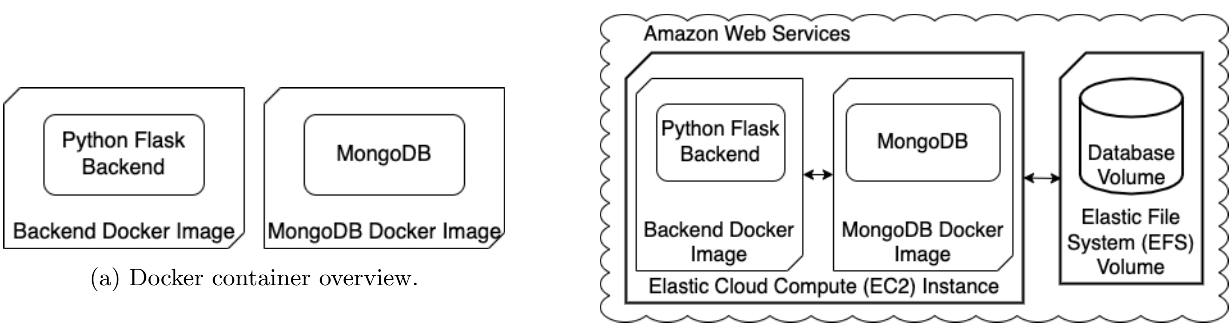
Python Flask: Python Flask[22] is a lightweight web application framework. Flask is utilized through the FlaskRESTful[23] library which is an extension on Flask to build out REST APIs. The TruePAL back-end server application is a FlaskRESTful REST API which then connects to other components such as the database and machine learning models.

MongoDB: MongoDB[24] is a multi-platform NoSQL database solution. MongoDB is used here by means of the mongoengine[25] Document-Object Mapper API for Python.

Docker: Docker[26] is a platform for "containerizing" applications into platform agnostic "Docker Images" which can then be run on all major operating systems and cloud providers. Docker creates images of the back-end server application to give the flexibility to deploy anywhere on any operating system.

Amazon Web Services: Amazon Web Services[27] (AWS) is one of the major cloud services providers. AWS hosts key pieces of cloud infrastructure for the TruePAL application, using multiple AWS Elastic Cloud Compute (EC2) Instances to run the containerized back-end applications along with the database software, and machine learning models. AWS Elastic File System (EFS) Instances are used store all of the TruePAL app data.

The TruePAL backend has also been deployed to Microsoft Azure[28] on a similar cloud set up with good results.



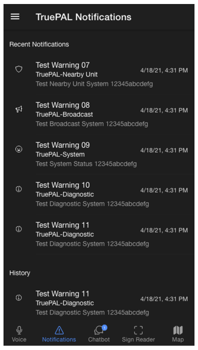
(a) Docker container overview.

(b) AWS overview for hosting the docker containers.

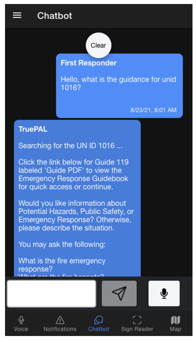
Figure 2: System layout for docker containers hosted on Amazon Web Services.

4.3 Cross Platform Mobile Application Core Features

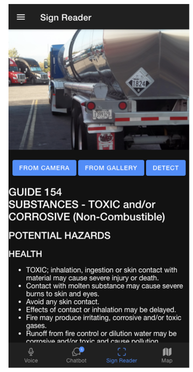
The Cross Platform Mobile Application has the following core features:



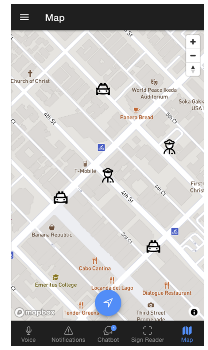
(a) Notifications



(b) Chatbot



(c) Hazard Sign Reader

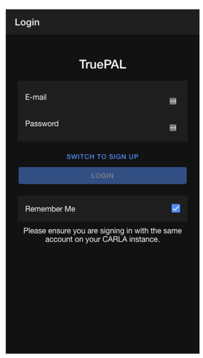


(d) Interactive Unit Map

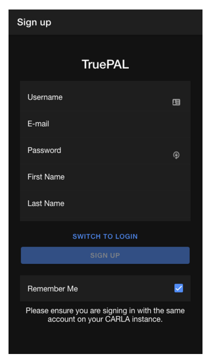
Figure 3: TruePAL App Core Features.

4.3.1 User Authentication

User Authentication: Allow multiple users (First Responders) to sign up and login to the system securely and concurrently.



(a) Login Screen.



(b) Signup Screen.

Figure 4: Authentication screens for the TruePAL App.

4.3.2 Notification and Alert System

Notification and Alert System: Provide a visual and audible alert / notification to the first responders. These alerts and notifications are issued by the NARS agent.

4.3.3 Chatbot

The Chatbot allows first responders to talk using colloquial and domain specific language using either text or voice to provide information and instructions for dealing with various scenarios. Responses by the chatbot are given both as text and text to speech.

4.3.4 Hazard Sign Reader and Analysis

The Hazard Sign Reader is able to analyze either a live photo or from the device gallery to perform a search on the hazardous materials database, and then provide the detailed guidelines on potential hazards and how to handle the substance.

4.3.5 Interactive Map

The Interactive Map displays the current users (first responders) location as well as other first responder locations, and other first responder vehicles, all in real time.

5. CONVERSATIONAL AI CHATBOT

Understanding the user by obtaining and incorporating the proper domain knowledge is the first step to acquiring trust in the technology. However, further methods to instill trust can be obtained during an exchanging interaction or afterwards, when inquiries are successfully answered.[29] In order for first responders to trust the application, there needs to be validation of being heard and being able to understand the first responders perspective. This allows the first responder to feel engaged and acknowledged through a dialogue transaction between themselves and the virtual assistant, which increases the likelihood to continue conversing.

The virtual assistant behind the TruePAL application allows first responders to access the information from the Emergency Response Guidebook through text input or voice activated inquiries. The speech to text feature gives the responder the option for hands-free usage therefore increasing focused attention on the main tasks. We performed a comparison between the different methods of accessing the domain knowledge.

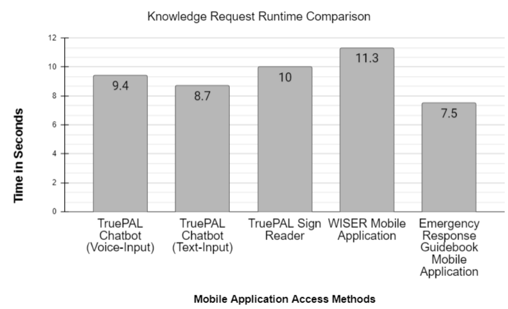


Figure 5: This Figure displays the differences in runtime of the mobile applications used to process the domain knowledge.

In Figure 5, a comparison is made between each method of accessing information. The data displays an average time resulting from a set of trial experiments conducted from users who understand the domain knowledge. Within the results, it is indicated that for the TruePAL chatbot with voice-input, there is noticeably an average of 1.9 seconds improvement time, compared to the widely used WISER application. The amount of seconds measured is critical in time sensitive emergency situations. Although the Emergency Response Guidebook Application demonstrates a faster run-time comparison compared to both applications, it is important to note that first responders must be familiar with the structure of the Emergency Response Guidebook in order to navigate through the ERG application. Whereas for the TruePAL chatbot and WISER application, the interface is designed to guide any type of user towards finding the knowledge needed. Thus, the comparison shows a reduction in burden related to paying close attention when utilizing multiple devices while searching through other resources. With the advantage of a voice-activated chatbot and a conversational dialogue method for accessing information, first responders receive a practical aid with the option to focus on more critical situations that require their full attention.

5.1 Conversation Design

Within our interviews with first responders, we learned about their processes and methods of accessing information on hazardous materials using the Emergency Response Guidebook and first aid. By conducting these interviews, we gained valuable insight applied to the design of our chatbot conversation flows. The resulting end product of the chatbot created a simple way to access the hazardous materials and first aid knowledge from the ERG. To access, a 4 digit identification number is required prior to any further inquiries being allowed. This method is used to set a context of the searched material identification and request to the chatbot. Thereafter, the chatbot prompts the user giving two method of access: (1) a handbook style to access the guidebook by prompting the user categories and subcategories to choose from and (2) a list of possible and common questions used to directly link to the subcategories or direct information in the guidebook.

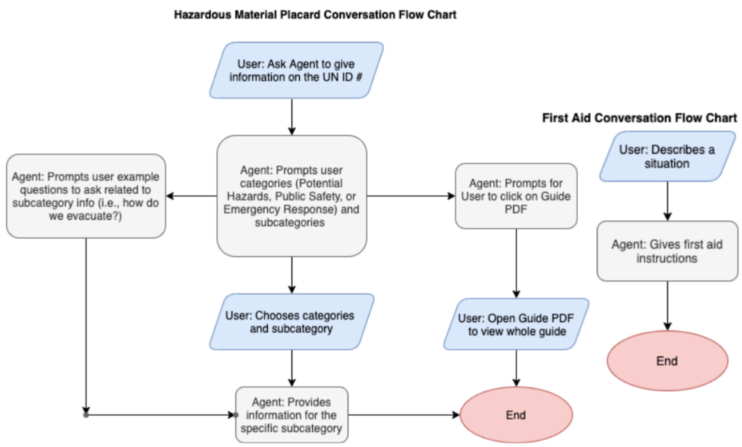


Figure 6: The AI conversational dialogue follows the flowchart starting with the user request.

Since a physical guide is still helpful, a clickable PDF link to an image of the guidance is provided when the user gives the identification number. To handle errors prompted by unidentifiable identification numbers, users are prompted to input an identifiable number. The decision to have the virtual assistant ask questions is based on a conversational dialogue design method. We understand the exchanging of questions and answers can reduce anxiety associated with smart devices and create a positive experience for the user.[30] In an interview with a firefighter, the firefighter revealed that many first aid emergency calls most often applied to first aid with hazardous materials rather than general first aid. When firefighters respond to emergencies of injuries from contact with hazardous materials, oftentimes they are unsure the precautions and respond immediately with general aid. This can cause further harm. Therefore, it is important for them to be reminded of dangers involved in order to protect themselves before helping the victim. In our development process, we were able to manipulate the conversation to accommodate to solving this particular discrepancy. In a straightforward procedure, the user gives the identification number to set the context while following up with inquiries to seek information on the first aid procedures under the specified identification category. Additionally, the user is able to type in their inquiries or record their voice-input to generate a visual and text-to-speech response. The functionality of the TruePAL virtual assistant allows for flexible use in both noisy and less noisy environments. This accommodation creates a better and trusted user experience.

5.2 Google Dialogflow

To implement our conversation into a lifelike interaction, we used Dialogflow which is a Google Cloud Platform service that allows developers to create conversational artificial intelligence using an interactive platform supported by machine learning (ML) and natural language processing (NLP). Through Dialogflow, we created a chatbot that is able to process unstructured data from natural human speech. With natural language understanding, smart recommendations are provided for the user. As a user expresses their intentions which in return evokes intents, similarly to the idea of information triggers, the user is able to register a context within the intent.[31] The intents are recognized through training phrases that are determined by the developer. The manipulation of the chatbot is very flexible due to the Dialogflow console. Furthermore, without changing the code within the TruePAL application, variations of training phrases may be added. Dialogflow includes an automatic speech recognizer, text-to-speech synthesizer, and permits developers to manage dialogues on a visual console.[32] As a result, the components of Dialogflow proved beneficial in producing conversation flows.

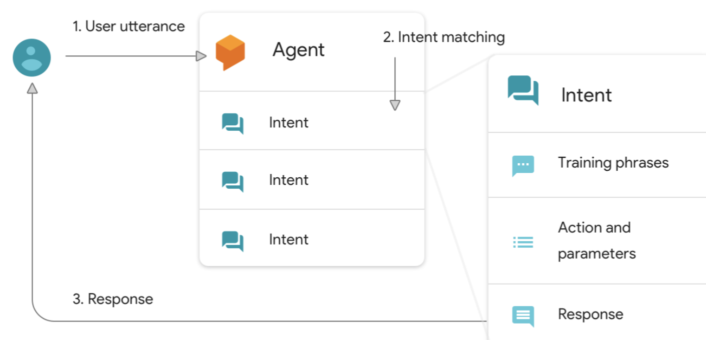


Figure 7: Overview of the inputs and outputs for Dialogflow.

6. HAZARD SIGN CLASSIFICATION AND GUIDANCE

The hazard sign reader analyzes sign images to produce the corresponding US-DOT Emergency Response Guidebook guidance. Signs in the image are first detected and then cropped out to be passed through optical character recognition. The hazard sign detection was performed using EfficientNet-D0 512×512 and BiFPN feature extractor.[33] This model was pretrained in TensorFlow[2] using the MSCOCO[34] database. EasyOCR[3] serves as the primary text extractor. Each text match found is used to look up the ERG hazard number database to search for any available guide. The detected bounding boxes are drawn on the image for classification verification and hazard guidances are returned to the user.

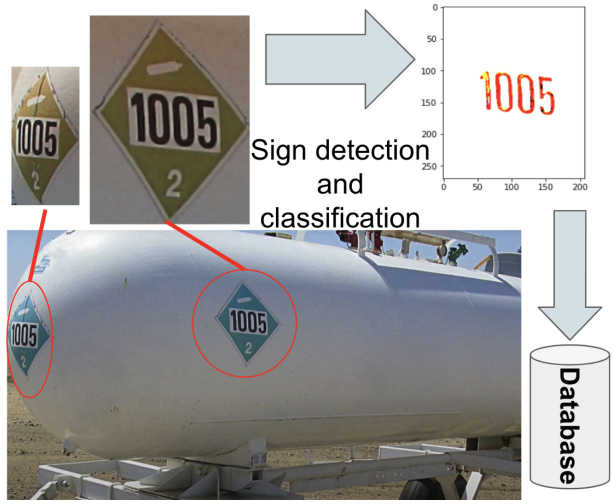
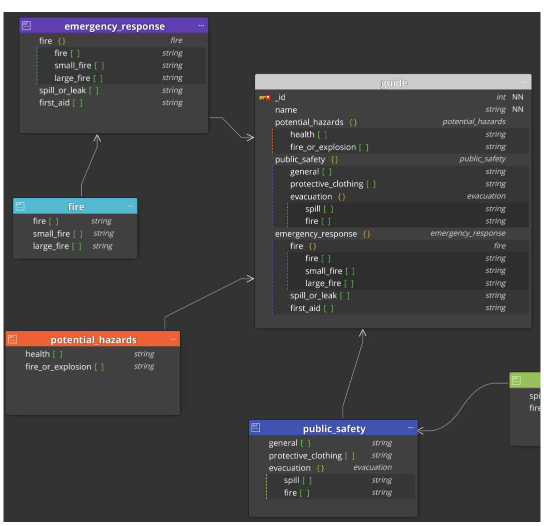


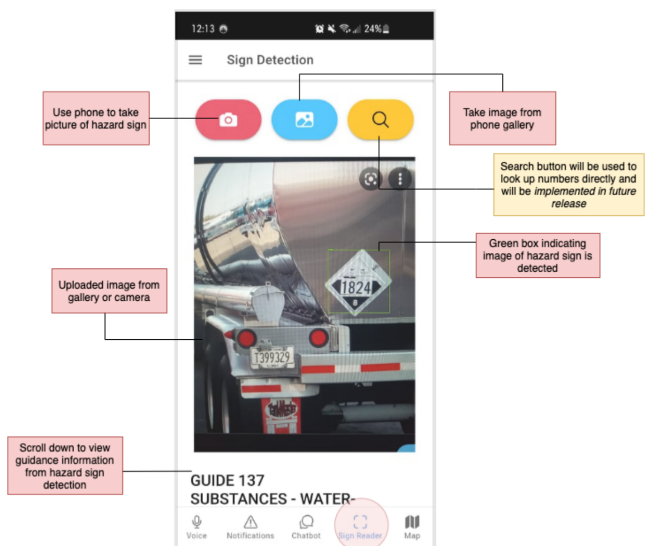
Figure 8: TruePAL's hazard sign classification process.

There are 127 digital images in the training data set, each with a hazard sign of different sizes, intensities, and skews. TF Data Augmentation[35] is used to enhance the diversity of our training data set. The preprocessing layer of our training data set includes resizing, rescaling, and random rotation. The training images show hazard signs from trucks, storage tanks, trains, and walls, and were manually labeled. This training set is then converted to sequences of binary strings by using TFRecord[36] so that images and annotations can be stored more efficiently and accessed more quickly.

Our model training experiments are conducted using a commodity workstation equipped with 2x RTX 2080 Ti with 64 GB of memory and installed with Ubuntu 20.04 LTS OS.



(a) Hazard Sign Database Schema.



(b) Hazard sign reader process and in-app display for the guide.

Figure 9: Hazard signage and ERG lookup database.

7. DISCUSSION

The development of conversational AI and trust in an artificially intelligent virtual assistant is still advancing in the work of first responders. Given the results from our studies, TruePAL's virtual assistant acts as an interpersonal chatbot, giving aid through responses that first responders have predetermined.[37] While an intrapersonal chatbot can be designed and incorporated, further data is needed to reveal the specific procedures that can be personalized. Due to Dialogflow's platform, new conversation flows can easily be generated and manipulated without making adjustments to the mobile application itself. Therefore, freedom to manually determine TruePAL's intents can increase trust in the usage of this aid. We envision TruePAL to become a trusted companion for first responders, but we understand that more research is needed to create statistically data driven dialogues.[32] We would like to better understand any gaps in procedures and discrepancies in emergency operations between first responder groups in order to provide AI-driven alternatives as a solution. With more data involved, TruePAL may be scaled to become commercially available. This will allow expanded usage by citizens for useful hazard and first aid knowledge, as well as a training tool for future first responders.

8. CONCLUSION

Developing an intuitive and easy to use AI chatbot assistant for first responders is a difficult task due to domain specific knowledge and verbiage not commonly used in regular conversations. The research done here shows the utilization in the advances from the commercial industry and open source projects in natural language understanding and optical character recognition. These easily accessible libraries were combined with the AGI NARS to produce a useful and effective virtual assistant prototype for first responders. The continuance of research for understanding the requirements of each specific group of first responders proves significant to further develop a trusted virtual assistant. By adjusting the virtual assistant to meet the needs of first responders, TruePAL can minimize the exposure to risks and reduce casualties.

ACKNOWLEDGMENTS

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